Coastal Engineering Technical Note

HEAVE COMPENSATION FOR HYDROGRAPHIC SURVEYING

PURPOSE: Improvements in hydrographic surveying technology, particularly depth measurement accuracy, have been supported by the Corps of Engineers. This note discusses state-of-the-art heave compensation methods as well as the development and commercial availability of heave correction equipment.

INTRODUCTION: Survey boat heave (vertical boat movement resulting from wave action) can be a major contributor to errors in depth measurements. In the past, manual or automatic smoothing of the data was the only practical way of partially correcting wave-induced errors. New techniques now give surveyors the opportunity to incorporate heave abatement equipment in their standard surveying operations and thereby produce higher quality surveys. Several approaches have been considered for measuring or alleviating heave-induced errors in hydrographic survey depth measurements. The most widely used approach has been to measure the survey boat motions, along with depth and position, and correct the motion-induced errors during post survey processing. A second approach has been to experiment with different hull designs for the purpose of reducing vertical boat motions to an acceptable level so that no corrections are necessary. A third approach is to separate the depth measurement transducer from the survey boat by using submerged, towed, or remote controlled transducer platforms. For several years, the Corps has been involved in a state-of-the-art search for techniques and equipment that could be used for the abatement of heave effects in Corps hydrographic surveys. Thus far, studies of the first two approaches have been made and are discussed herein. The National Oceanic and Atmospheric Administration (NOAA) has been involved in a similar program. NOAA and the Corps have coordinated common development paths in their respective heave study programs to avoid undesirable duplication of effort.

EVALUATION OF A GYRO-STABILIZED HEAVE COMPENSATION SYSTEM: A gyro-stabilized heave compensation system (Krupp-Atlas HECO-10) is installed on a Corps survey boat in the Portland District. This system incorporates an accelerometer mounted on a platform that is maintained in a fixed vertical orientation by a gyroscope. Measurement signals generated by this system include (1) vertical acceleration, (2) pitch angle, and (3) roll angle. Vertical displacement is computed by double integration of the vertical acceleration measurements. These measurements are recorded at the same time that depth and position measurements are made during surveys. Raw depth measurement data are corrected using the computed vertical displacement of the boat. Transducer pointing errors in the raw depth measurements can also be corrected by computations using the pitch and roll angle measurements. Software modifications have been made to the existing survey system to incorporate the additional inputs. Experience to date indicates that this heave compensation hardware and software will function reliably under typical survey operating conditions. Users feel confident that depth accuracy is improved using this equipment. Figure 1 illustrates the principle embodied in this means of measuring heave.

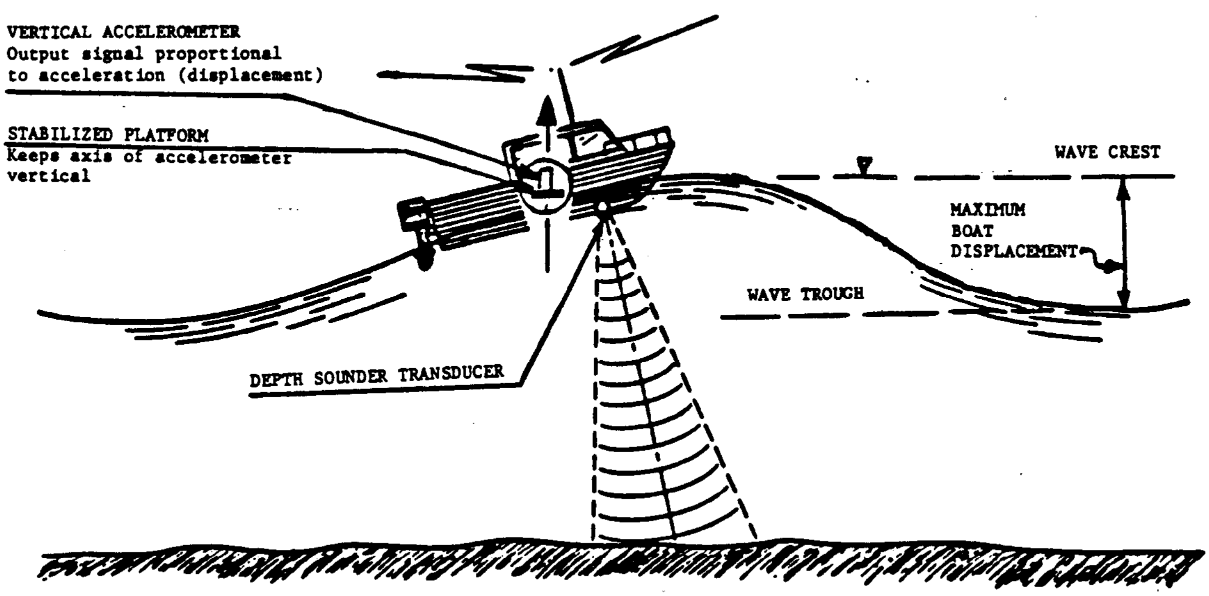

Figure 1. Measurement of vertical acceleration

EVALUATION OF PENDULUM-STABILIZED HEAVE COMPENSATION SYSTEM: A heave compensation system made by Datawell (HIPPY-120) was installed on a Corps District survey boat. This system makes the same measurements as the system described above with the accelerometer platform stabilized by a pendulum mechanism instead of a gyro. A pendulum stabilized platform is simpler and less expensive than a gyro-stabilized accelerometer platform but less accurate during turns and speed changes. Heave, roll, and pitch are recorded at the same time that depth and position measurements are made. The HIPPY-120 incorporates a dedicated microcomputer that performs the double integration computations. This system provides two heave signal outputs: one real time and the other delayed by approximately 77 sec. The delay is necessary for the computer to adjust for baseline drift and is considerably more accurate than the real time heave signal. Software was written to incorporate the heave system measurements into the existing survey system. The HIPPY-120 hardware functioned for more than a year without any problems during normal survey operations. However, problems with the modified software caused the surveyors in the district to lose confidence in the system. The Datawell system has now been transferred to a survey boat in another district for further evaluation using different system software. This heave compensation system is best adapted to large survey boats operating in broad channels or bays where long survey lines are run at constant speeds.

EXPERIMENTS WITH DOPPLER EQUIPMENT: The basic doppler principle states that relative motion between a sound transmitter and a receiver will cause a change in the frequency of the received signal f_R with respect to the transmitted signal frequency f_o. This principle is presented in Figure 2.

When the transmitter and receiver are moving toward each other, the frequency is shifted higher. When the transmitter and receiver are moving apart, the frequency is shifted lower. The frequency shift is directly proportional to the relative velocity between the signal transmitter and receiver. In Figure 2, the transmitter and receiver are both on the same boat and do not move relative to each other. The signal reflected from the bottom is affected by boat motion in a manner that causes the signal at the receiver to be shifted as if the receiver were moving relative to the transmitter. In the above example, the signal frequency will decrease as the boat moves upward as

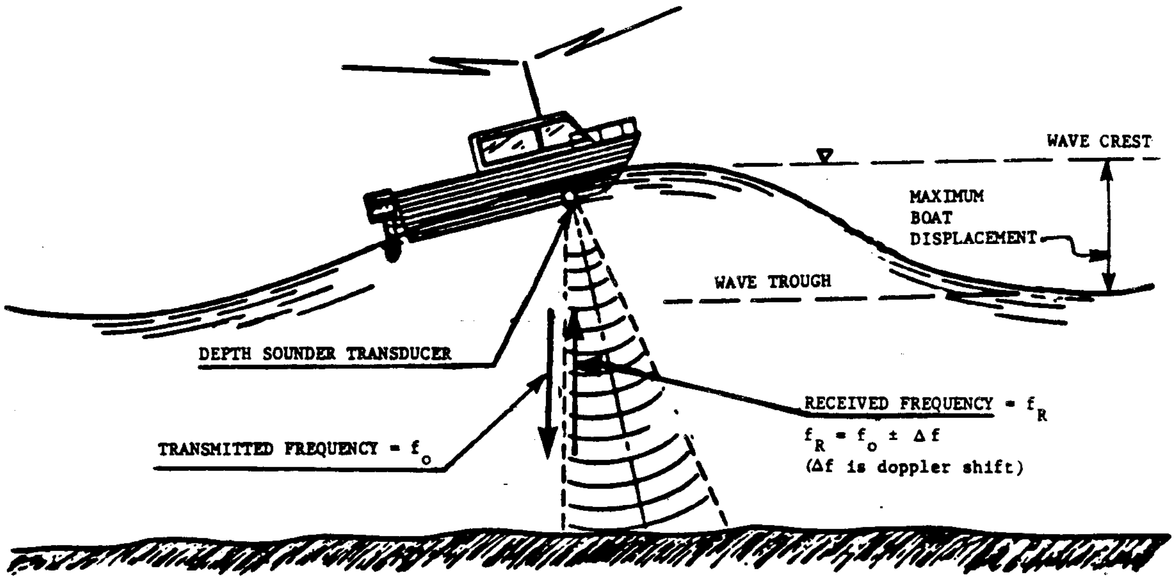

Figure 2. Doppler vertical motion detection principle

a result of wave action. This frequency shift is used to compute vertical boat motion. Vertical velocity is first determined from the frequency shift, and this in turn can be integrated once to get displacement. The doppler principle works for light, microwaves, and acoustic energy. Highway patrol "speed guns" are a widely used example of microwave doppler instruments. For hydrographic survey work, acoustic energy is ideal because underwater attenuation is very low. A heave correction system based on the doppler principle is marketed by the Navatronic Corporation in Denmark. The Navatronic system uses the same transducer for both depth and vertical motion measurements.

EVALUATION OF SWATH HULL SURVEY BOAT DESIGN: The Portland District is evaluating an experimental boat hull design that minimizes boat heave. This design, shown in Figure 3, uses twin submerged flotation hulls for support of a cabin that remains above water. Small control fins attached to the flotation hulls are used for dynamic control of heave, pitch, and roll. The small waterplane area twin hull (SWATCH) design has a relatively small change in static flotation force for waves smaller than the spacing between the flotation tanks and the deck. This is due to the small cross-sectional area of the struts connecting the upper and lower hulls. The SWATH type hull is therefore much more stable than a displacement hull.

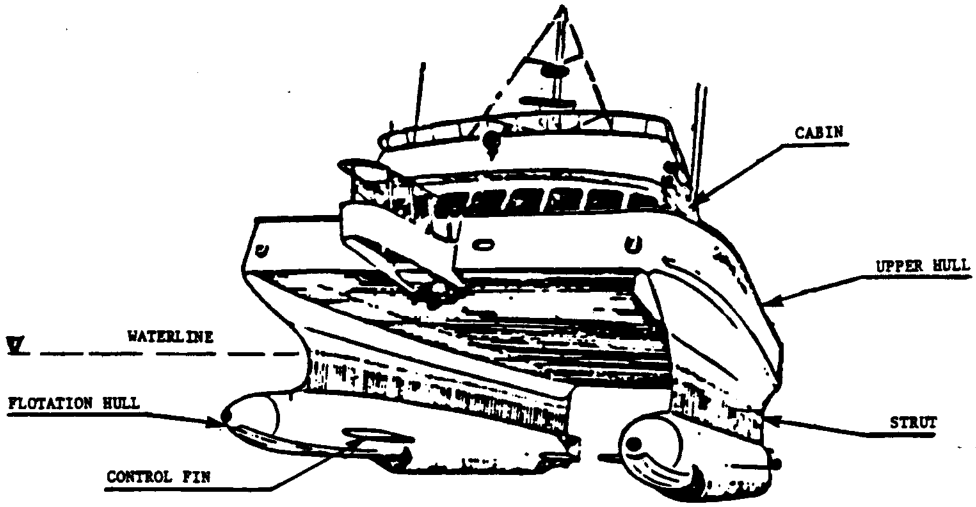

Figure 3. Small waterplane area twin hull (SWATH)

SUMMARY: Heave errors can be "designed out" of survey boats or electronically compensated for. Heave measuring instruments can provide data that will permit better heave correction of depth data than is possible with manual methods. These corrections can best be obtained by digital techniques and employed during post survey plotting. The state of the art is rapidly changing and therefore justifies the need for continued evaluation of modern heave measuring equipment, radical hull designs, and other alternate means of transporting depth sensors.

AVAILABILITY: Equipment for correcting heave-induced erors in depth measurements is available from:

Source	Telephone Number	Type System
Krupp Atlas 1453 Pinewood Street Parkway, New Jersey 07065	(201) 388-1500	Gyro-Stabilized Accelerometer
Datawell NV Zomerluststraat 4 Haarlem-Holland 31477	(023) 316519	Pendulum-Stabilized Accelerometer
Navatronic/Klein Assoc. Klein Drive Salem, New Hampshire 03079	(603) 893-6131	Doppler

At present, there are no known United States manufacturers of heave correction equipment suitable for Corps surveying work. The market is not large, and United States manufacturers will not respond until they can sense that the potential market is growing. Until this occurs, the European manufacturers will continue to be the primary source of heave measuring equipment.

ADDITIONAL INFORMATION: Contact Mr. George Downing, Special Services Branch, WES Instrumentation Services Division, at (601) 634-2537 or Mr. Timothy Fagerburg, Prototype Evaluation Branch, WES Hydraulics Lab, at (601) 634-2257

REFERENCES:

Downing, G. C., Fagerburg, T. L., and Hart, E. D. 1985 (in preparation). "Evaluation of Vertical Motion Sensors for Potential Application in Corps Hydrographic Surveying," Technical Report, Hydraulics Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Pryor, D. May 1982. "Characterization Tests at Datawell HIPPY 120c Vessel Motion Sensor," NOAA Technical Report OTES-8, US Department of Commerce, NOAA, Rockville, Md.